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Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine
(2025) 33:138
https://doi.org/10.1186/s13049-025-01444-w

Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine

RESEARCH Open Access

Endotracheal intubation during cardiac arrest by critical care paramedics: a service evaluation of success rates following structured education

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Abstract

Background Endotracheal intubation is an important pre-hospital intervention in critically ill patients. However, it can be a challenging skill, and previous studies have highlighted varying success rates. The European Resuscitation Council (ERC) have set a clear target of a greater than 95% success rate within two attempts, for all clinicians who provide endotracheal intubation during cardiac arrest. This service evaluation looks to explore the impact of training and education on the intubation performance of critical care paramedics.

Methods Retrospective data was collected from a single service over a six year period, from April 2019 to December 2024. During that time period, a number of educational or organisational interventions were introduced, with the aim of improving endotracheal intubation success rates. Data from all intubation attempts for patients in cardiac arrest by critical-care paramedics working with the Devon Air Ambulance Trust were recorded. The primary outcome was the rate of success of endotracheal intubation within two attempts. Secondary outcomes included the rate of first-pass success and the number of patients who had a failed first intubation attempt and did not receive a subsequent attempt. A Chi-squared statistical test was used to judge the significance of change between data from the years 2019 and 2024.

Results 390 patients were included and reviewed. Between 2019 and 2024, success rates within two attempts improved by 7.9% points ($\chi^2 = 4.205$, $p = 0.040$), while first-pass success rates improved by 18.4% points ($\chi^2 = 7.125$, $p = 0.0076$). The success rate within two attempts at endotracheal intubation in 2024 was 97.7%. Over the whole time period, intubation was successful within two attempts in 94.6% ($n = 369$) of patients, while the first-pass success rate was 82.6% ($n = 322$). Of the 68 patients who had an unsuccessful first intubation attempt, 19.1% ($n = 13$) did not receive a second attempt.

Conclusions Implementation of a training and education programme was associated with a significant improvement in endotracheal intubation success rates within the service. With dedicated training, critical care

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paramedics demonstrate safe and effective endotracheal intubation for patients in out-of-hospital cardiac arrest, meeting the ERC recommendations of a greater than 95% success rate within two attempts at intubation.

Keywords Intubation, Critical care, Paramedics, Paramedicine, Education, Emergency medicine, Resuscitation, Airway

Introduction and background

Endotracheal intubation (ETI) describes the process of laryngoscopy and insertion of an endotracheal tube into the trachea. In the pre-hospital setting, this is generally to prevent aspiration and aid ventilation and oxygenation in cardiac arrest, or in the context of a pre-hospital emergency anaesthetic (PHEA).

The European Resuscitation Council (ERC) recommends that only rescuers with a 'high success rate' should attempt ETI during resuscitation, with that defined as a greater than 95% success rate within two attempts [1]. For practitioners who do practice pre-hospital intubation, ERC guidelines mandate that they undertake competency-based training, as well as regular opportunities to refresh skills [1].

However, within out-of-hospital cardiac arrest, several studies have demonstrated that routine ETI does not improve, and may even worsen, outcomes [2–4]. The AIRWAYS-2 trial found that patients randomised to ETI during cardiac arrest did not have significantly improved neurological outcomes, when compared to those treated with supraglottic airway devices (SGAs) [2]. Moreover, intubation is recognised as a technically challenging skill; the 'Pragmatic Airway Resuscitation Trial' (PART) demonstrated an initial ETI success rate of only 51.6% amongst North American emergency medical service (EMS) personnel [3, 5]. In a UK setting, paramedics enrolled in the AIRWAYS-2 trial achieved ventilation within two attempts at intubation in 79% of patients [2].

Regular exposure to intubation, either in simulated or real clinical settings has been associated with improved success rates [6–8], but these opportunities are uncommon in the UK outside of specialist practice [9]. The Association of Ambulance Chief Executives (AACE) advised the authors (NL) through personal communications that, as of 2023, only 36% ($n = 5/14$) of ambulance services permit intubation for non-specialist paramedics. Outside of these trusts, ETI is limited to specialist clinicians, including critical care paramedics (CCPs) and some Hazardous Area Response Team (HART) paramedics. The UK picture of paramedic-led ETI is not static and differs depending on the population served by each ambulance service. However, at the time of publication, less than half of UK-based non-specialist paramedics have ETI within their scope of practice.

Methods

Design

This service evaluation uses retrospective data collected over a six-year period from CCPs working with the Devon Air Ambulance. The study aims to demonstrate improvements in intubation rates for patients in cardiac arrest, alongside a structured educational programme.

Setting

Devon Air Ambulance Trust (DAAT) is one of 21 air-ambulance charities in the UK, operating two helicopters and one critical-care car. In 2024, they were tasked to 2459 calls, of which 383 were cardiac arrests.

DAAT operate a single-CCP crew on the response car and either a dual-CCP crew or single doctor/CCP crew on the helicopters. The CCP-crewed car was introduced in Autumn 2021, while the other vehicles were present throughout the study period. The duel-crewed vehicles utilise an interchangeable operator model (ICOM), and the CCP is typically allocated to perform intubation if required during cardiac arrest.

The CCPs included in this paper have all completed additional formal postgraduate study in 'pre-hospital critical care, retrieval and transfer', prior to independent practice.

Use of a bougie has been standard practice for all intubations carried out by DAAT CCPs throughout the included period. Video laryngoscopes were recommended by DAAT as the laryngoscope of choice, although their use is not mandated. DAAT CCPs are trained to use '30-second drills', as described by Sydney HEMS [10], to optimise laryngoscopy views, particularly following an initial unsuccessful attempt.

Definitions

For the purposes of this paper, an intubation attempt is defined as a single placement of a laryngoscope within the oropharynx, with the aim of inserting an endotracheal tube into the trachea.

Success was defined as the ability to ventilate the patient through the placed endotracheal tube, including confirmation with end-tidal carbon dioxide ($EtCO_2$) monitoring. Inability to insert the endotracheal tube into the trachea, or the absence of a confirmatory $EtCO_2$ waveform was defined as a failed ETI attempt.

Outcome measures

The primary outcome measure was the rate of success of ETI within two attempts. This will also be termed 'overall success'.

Secondary outcome measures included:

- First-pass success; that is, ETI which was successful on the first attempt.
- Number of patients who had a failed first ETI attempt and did not receive a subsequent ETI attempt.

Inclusion and exclusion criteria

All patients included had an attempted intubation from a CCP for the purpose of ventilation in out-of-hospital cardiac arrest. This included both traumatic and non-traumatic causes.

Patients who received ETI from a physician were excluded from analysis.

Patients who had one attempt at ETI followed by an alternate airway management strategy were included in analysis as a failure to intubate within two attempts.

Patients who had laryngoscopy purely for foreign body airway obstruction (FBAO) removal were not included.

Structured interventions

A number of organisational interventions, including educational courses, practical training and video laryngoscopy attempt review/debrief sessions have been conducted over the course of six years. Table 1 is a complete list of formal interventions.

Data collection

The success and number of ETI attempts was self-reported in patient records (HEMSBase clinical record software) by the intubating clinician, as routinely collected data. Electronic patient records were subsequently interrogated to identify all cases of cardiac arrest in which a CCP attempted ETI. Data from between 1 April 2019 and 31 December 2024 was extracted and collated by the DAAT quality improvement and research officer.

The study was initially proposed in January 2020, with final approval from the trust to proceed granted in April 2024.

Statistical analysis

Data is presented with descriptive statistical analysis. A chi-squared statistical test was used to determine the significance of variation in both first-pass and overall ETI success rates. This was an appropriate test to compare categorical data across multiple independent years. Microsoft Excel 2024 (Microsoft Cooperation) was used for data analysis.

Results

Between 1 April 2019 and 31 December 2024 there were 390 patients in cardiac arrest who received ETI from a CCP (Table 2).

The primary outcome, successful ETI within two attempts, was achieved in 94.6% ($n=369$) of patients across the whole time period. Of those, the first attempt at ETI was successful in 82.6% ($n=322$) of cases.

Table 1 Educational or organisational interventions to improve ETI success rates

Date	Educational or Organisational Intervention
Jan 2018	Introduction of theatre placements for CCPs, for 3 days per year. CCPs typically intubate three to six patients per-day.
Apr 2018	DAAT implement recommendations from College of Paramedics consensus statement on intubation [11]. Paramedics now require 60 supervised intubations before being deemed competent, of which at least 25 must be undertaken in a controlled setting (i.e. a hospital anaesthetic room). Further requirement for an ongoing and regularly-reviewed airway management logbook. This records all intubation attempts, including training, simulation and clinical practice.
Nov 2019	Locally agreed protocol released which stipulates that intubation during PHEA to be limited to critical care doctors. CCPs remain able to intubate in cardiac arrest.
Mar 2020	Intubation briefly removed from the scope of practice for all Trained CCPs in response to the developing SARS-CoV-2 pandemic. Reintroduced two weeks later with the addition of appropriate personal protective equipment.
Jun 2020	Locally agreed intubation guideline published.
Nov 2020	Intubation removed from scope of practice for all paramedics within the South-West Ambulance Service (SWAST), with the exception of trained CCPs or HART paramedics.
Sep 2021	Expansion of theatre placements to a designated three week placement for all trainee CCPs
Sep 2021	Local literature review of video versus direct laryngoscopy to inform local practice
Jan 2022	Introduction of C-MAC video laryngoscope (Storz, C-MAC Pocket monitor 8403XD) to DAAT helicopters and cars
Aug 2022	Local policy introduced to recommend video laryngoscopy as first-line intubation method. Database established to record and review video laryngoscopy attempts.
Jan 2023	Cadaveric surgical skills training session for CCPs, including airway management and intubation opportunities.
Jul 2023	Formal video laryngoscope database recordings review session with team using recorded cases from previous year.
Feb 2024	Repeat cadaveric surgical skills training session for CCPs, including airway management and intubation opportunities.
Apr 2024	Formal video laryngoscope database recordings review session with team using cases since July 2023

Table 2 Endotracheal intubation success rates per year

Year	Total patients (*n*)	First-Pass Success (*n*)	Attempted Second Pass (*n*)	Second Pass Success (*n*)	First-Pass Success (%)	Success within two Attempts (%)
2019	59	40	16	13	67.8	89.8
2020	40	32	6	5	80.0	92.5
2021	57	51	4	4	89.5	96.5
2022	69	59	7	5	85.5	92.8
2023	78	65	11	10	83.3	96.2
2024	87	75	11	10	86.2	97.7
Totals	**390**	**322**	**55**	**47**	**82.6**	**94.6**

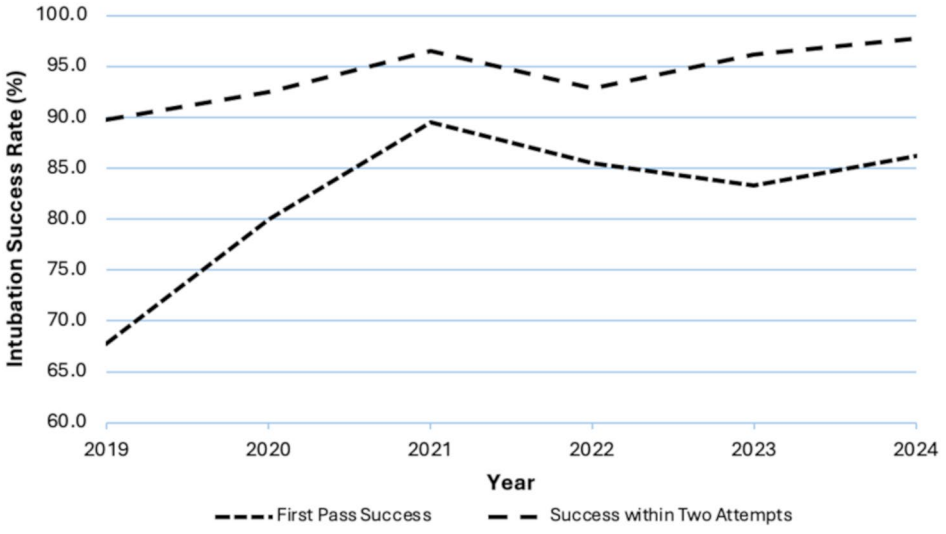

Fig. 1 Endotracheal Intubation Success Rates per Year

Table 3 ETI success within two attempts if those who received alternate airway management as a second attempt are excluded

Year	Total patients (*n*)	First-Pass Success (*n*)	Attempted Second Pass (*n*)	Did not attempt Second Pass (*n*)	Second Pass Success (*n*)	Theoretical Success within two Attempts (%)
2019	*59*	*40*	*16*	*3*	*13*	*94.6*
2020	*40*	*32*	*6*	*2*	*5*	*97.4*
2021	*57*	*51*	*4*	*2*	*4*	*100.0*
2022	*69*	*59*	*7*	*3*	*5*	*97.0*
2023	*78*	*65*	*11*	*2*	*10*	*98.7*
2024	*87*	*75*	*11*	*1*	*10*	*98.8*
Totals	***390***	***322***	***55***	***13***	***47***	***97.9%***

Over the course of six years (comparing 2019 to 2024, Fig. 1), first-pass success rates improved by 18.4% points to 86.2% in 2024 ($\chi^2 = 7.125$, $p = 0.0076$). Overall ETI success rates improved by 7.9% points to 97.7% in 2024 ($\chi^2 = 4.205$, $p = 0.040$).

Of the 68 patients who had an unsuccessful first ETI attempt, 80.9% ($n = 55$) went on to receive a second ETI attempt, while 19.1% ($n = 13$) received an alternate airway management strategy. Out of those who received a second ETI attempt, the 'second pass' was successful in 85.5% (n = 47) of patients.

If only patients with two physical attempts at ETI are analysed, the 'theoretical' ETI success rate within two attempts was 97.9% ($n = 369/377$) across the studied time period. Table 3 provides a year-by-year breakdown of success rates when excluding patients without two physical ETI attempts.

Discussion

The educational and organisational interventions described in this review were associated with a significant improvement in both 'success within two attempts' and 'first-pass success' throughout the time period.

While it is impossible to determine the exact impact of individual interventions, it is likely that other, external, factors also contributed to the performance improvement. For example, DAAT policy was modified in August 2022 to recommend the use of video laryngoscopy (VL) as a first-line technique for all ETI attempts. In similar pre-hospital settings, VL has been associated with a significantly higher first-pass rate than direct laryngoscopy [12]. It is therefore plausible that the increasing use of VL played a role in the results seen in this evaluation.

When translating the ERC recommendations on targets for intubation success rate, it is uncertain to the authors whether patients should be included for analysis when only one attempt at ETI was made, before then moving to a different ventilation strategy.

There are several reasons why a second attempt at ETI might not be performed after a failed first attempt. Some patients may have experienced a return of spontaneous circulation (ROSC) following an unsuccessful first ETI attempt, but prior to the second attempt. Likewise, in the dynamic and changeable environment of a cardiac arrest, 'Do Not Resuscitate' plans may only be revealed after one attempt at ETI. Initial laryngoscopy may also demonstrate distorted or unrecognisable anatomy which would preclude further ETI attempts. Early use of an alternate, 'rescue', airway management strategy represents pragmatic decision making, in line with the 'Vortex' approach [13].

Ultimately, patients who received an alternate airway management strategy after one attempt at ETI were included in our primary analysis as 'failure to intubate within two attempts'. This is because it was felt that excluding this cohort of patients may lead to an artificially elevated ETI success rate.

While results broadly align with other similar studies [14, 15], it is challenging to make direct comparisons. For example, results from specialist critical-care paramedics on the south coast of England demonstrated a first-pass success rate of 81.5% and success within two attempts in 96.7% of patients [14]. Yet, this study did not appear to include patients who had one attempt at ETI followed by an alternate strategy. The largest UK-based pre-hospital airway management trial, AIRWAYS-2 [2], demonstrated successful ventilation after up to 2 attempts at ETI in 79.0% of patients. However, the clinicians involved in AIRWAYS-2 were mostly non-specialist paramedics; as such, the rates of success of ETI cannot be compared to DAAT CCPs who have significant additional training.

It is also worth noting that the total number of intubations performed in 2020 was lower than that of the preceding or following years. This was likely as a consequence of temporary removal of ETI from DAAT protocols during the ongoing SARS-CoV-2 pandemic. ETI was subsequently reintroduced in-line with government and Resuscitation Council UK guidance [16, 17], including use of level three personal protective equipment (PPE) for all involved clinicians. There was, however, probable residual uncertainly and challenges associated with donning and doffing PPE which contributed to a lower ETI rate for the remainder of the pandemic.

An increased number of ETI attempts from 2022 onwards was likely influenced by the introduction of an additional single-crewed CCP vehicle in Autumn 2021, which increased DAATs response capacity. Moreover, the removal of ETI from the scope of practice of non-specialist SWAST paramedics in November 2022 may account for a compensatory rise in the rate of DAAT-performed ETIs.

Limitations

Although there was a significant improvement in both first-pass and overall ETI success rates from 2019 to 2024, it is important to consider this in the context of the study size. Looking at the difference in first-pass success rates from these two years, the fragility index is 4, while the fragility quotient is 0.027. This means that 4 patients in 2024 who had a successful first-pass ETI would have needed to have a failed first attempt to make the improvement non-significant, when calculated with a two-tailed Fisher's exact test. For context, a systematic review of 56 randomised controlled trials in critical care medicine identified a median fragility index of 2 [18]. The fragility index for overall ETI success was 0, indicating that the significant result calculated with a chi-squared test is statistically fragile.

As data was self-recorded by intubating CCPs, there is an intrinsic risk of reporting bias. This would be challenging to mitigate without having an independent researcher present for all intubations. Recall bias was minimised by having an independent DAAT research officer collate data directly from patient records.

Future research

First-pass success is not the only performance indicator that could be evaluated when considering ETI for out-of-hospital cardiac arrest. While 'high ETI success rates' sit within ERC guidance for advanced airway management in cardiac arrest, it is important to ensure that task focus doesn't compromise further aspects of care. Future research could quantify interruptions to chest compressions or 'length of look' during laryngoscopy.

Conclusions

Structured educational and organisational interventions were associated with significant improvement in both 'overall' and 'first-pass' ETI success rates, for CCPs treating patients in out-of-hospital cardiac arrest.

This study demonstrates that the ERC standard of a 'ETI success rate of greater than 95% within two attempts' can be met by CCPs working in a pre-hospital environment. As such, the results support the ongoing provision of ETI by appropriately trained specialist paramedics.

Abbreviations

AACE	Association of Ambulance Chief Executives
CCP	Critical Care Paramedic
DAAT	Devon Air Ambulance Trust
EMS	Emergency Medical Service
ERC	European Resuscitation Council
$EtCO_2$	End-tidal Carbon Dioxide
ETI	Endotracheal Intubation
FBAO	Foreign Body Airway Obstruction
HART	Hazardous Area Response Team
ICOM	Interchangeable Operator Model
PART	Pragmatic Airway Resuscitation Trial
PHEA	Pre-Hospital Emergency Anaesthetic
PPE	Personal Protective Equipment
ROSC	Return of Spontaneous Circulation
SGA	Supraglottic Airway
VL	Video Laryngoscopy

Acknowledgements

We would like to thank Dr Crispin Musicha from the University of Plymouth for his help and guidance on statistical analysis.

Author contributions

TA performed data analysis and was a major contributor in writing the manuscript. SL was responsible for conceiving the research idea and contributing to the discussion. NL was responsible for data collection, project supervision and provision of background information. All authors read and approved the final manuscript.

Funding

TA, SL and NL received no individual funding in connection with this manuscript. Open Access funding enabled by Devon Air Ambulance Trust.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Ethical approval is not required, since this service evaluation did not collect information beyond routinely collected data, nor did it modify standard practice within the studied setting. The service evaluation was registered with the Devon Air Ambulance Trust.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 25 February 2025 / Accepted: 7 July 2025
Published online: 12 August 2025

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